RESPONSE OF WINTERFAT (*CERATOIDES LANATA*) COMMUNITIES TO RELEASE FROM GRAZING PRESSURE

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ABSTRACT.—Sixteen study sites were established in grazed and ungrazed stands of winterfat in Kane County, Utah. The area is located within the winter range of cattle and along U.S. Highway 89 between Kanab, Utah, and Page, Arizona. Road construction in 1957 dissected several winterfat communities, and following fencing part of the communities were released from grazing. Differences in species composition, vegetation, and soil characteristics between grazed and ungrazed sites were assessed. Major differences in site characteristics appeared due to the influence of winter grazing by cattle. Winterfat and Indian ricegrass showed increased cover on the nongrazed sites following release from grazing pressure. Winterfat also showed significant negative interspecific association patterns with all major species.

Winterfat (*Ceratoides lanata* [Pursh] J. T. Howell) is considered a valuable forage component of winter ranges throughout western North America. Blauer et al. (1976) described winterfat as "superior nutritious browse for livestock and big game." Griffiths (1910) pointed out that winterfat is "very much injured by overgrazing." However, more recent research has provided somewhat conflicting information relative to the tolerance of winterfat to grazing pressure. Holmgren and Hutchings (1971) indicated that percent plant cover represented by winterfat sharply declines under heavy grazing during late winter.

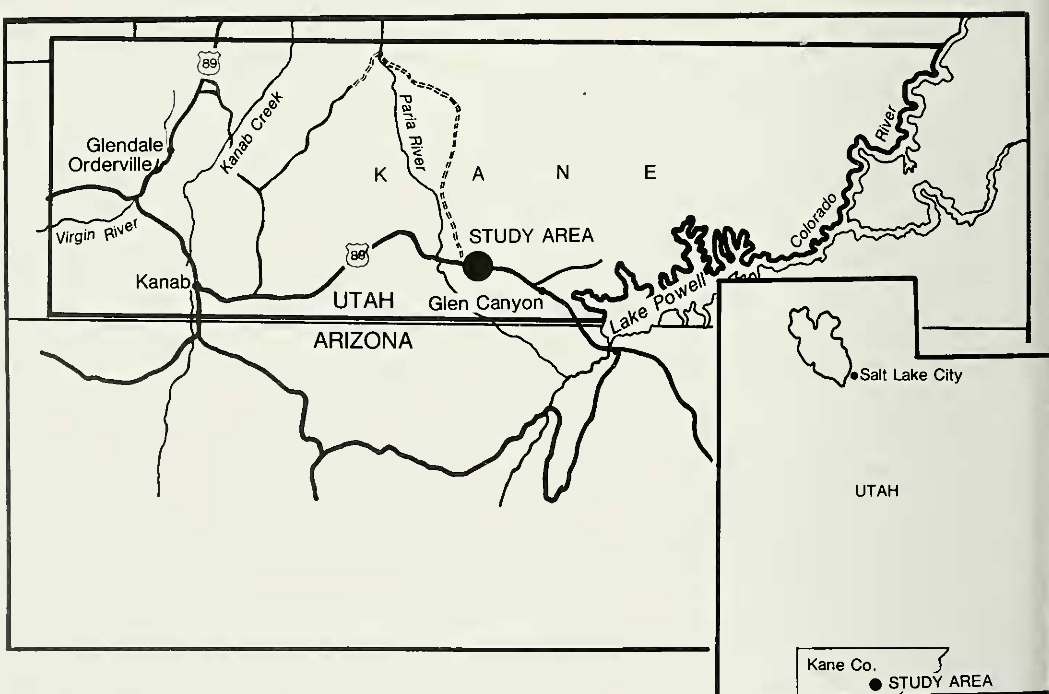

Fig. 1. Map of study site location in Kane County, Utah.

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TABLE 1. Means and standard deviations (SD) of soil factors and significance levels for the difference between the means for the grazed and nongrazed winterfat populations in Kane County, Utah. Significance levels were computed by using the student's t-statistic.

SITE FACTOR	GRAZED		UNGRAZED	
	Mean	SD	Mean	SD
Sand (%)	83.8	2.42	83.1	2.94
Silt (%)*	8.2	1.12	9.2	0.83
Clay (%)	8.6	2.47	7.6	2.98
Organic matter (%)*	0.3	0.05	0.2	0.05
pH	8.0	0.05	7.8	0.05
EC $\times 10^3$	0.5	0.05	0.6	0.36
CEC (meq/100 g)	8.6	1.31	8.8	1.32
Calcium (ppm)*	5194.0	768.0	4375.0	1040.0
Magnesium (ppm)	109.5	32.6	177.0	26.5
Sodium (ppm)	13.3	6.26	25.6	47.3
Potassium (ppm)	226.9	45.1	264.8	90.8
Iron (ppm)	1.4	0.24	1.3	0.11
Manganese (ppm)	2.7	0.57	2.6	0.35
Zinc (ppm)	0.6	0.27	0.6	0.21
Copper (ppm)	0.4	0.05	0.4	0.07
Phosphorus (ppm)	31.0	5.31	37.0	8.44

*Significant difference between means at .05 level.

Trlica and Cook (1971) showed that winterfat did not make good growth recovery under any defoliation treatment. Yet, Norton (1978) states that winterfat is "relatively indifferent to heavy grazing."

The purpose of the present study was to examine changes in winterfat communities following 26 years of release from grazing pressure on ranges in Kane County, Utah.

STUDY AREA

U.S. Highway 89 from Kanab, Utah, to Page, Arizona, was constructed during 1957, and the right-of-way was fenced. This construction dissected winterfat communities 5 km east of the Paria River, creating grazed and ungrazed units (Fig. 1).

The area is located within the Bureau of Land Management East Clark Bench allotment. This allotment has been utilized primarily as winter range for cattle since 1956. Although entry and removal dates for livestock have varied, 1 November to 31 May was the general season of use until 1964, when the removal date for livestock was moved back to April 30.

The climatic conditions of the study area are similar to conditions at Glen Canyon City, Utah, 15 km east along U.S. 89. Average annual precipitation in the area varies from 15 to 20 cm. There are two main periods of precipitation, one beginning in December and ending in March in the form of snow and the second beginning in August and ending in October in the form of rain (Green et al. 1981). The hottest month of the year is July, with an average temperature of 28 C. The coldest month is January, with an average temperature of 0 C. The frost-free period for the area begins in late April and ends in late October, averaging 190 days (U.S. Environmental Data Service 1968).

METHODS

Sixteen stands were sampled during June and July 1984 (eight each within grazed and ungrazed sites), and data were collected to represent conditions within grazed and ungrazed winterfat communities. Each stand was subsampled, with a total of 11 1-m^2 quadrats placed one every 3 m along 33-m transect lines. Transects within the protected sites were placed parallel to and equidistant between the fence line and U.S. Highway 89. Transects within the grazed sites were placed parallel to transects in protected sites and at equal distances from the fence line.

Total living cover of vascular plants was estimated in each quadrat. Cover by life forms, soil cryptogams, litter, exposed rock, bare ground, and individual plant species were estimated using Daubenmire's cover classes (1959).

Three soil samples were taken at 10-m intervals along each transect line from the top 20 cm of soil. The three samples were later combined

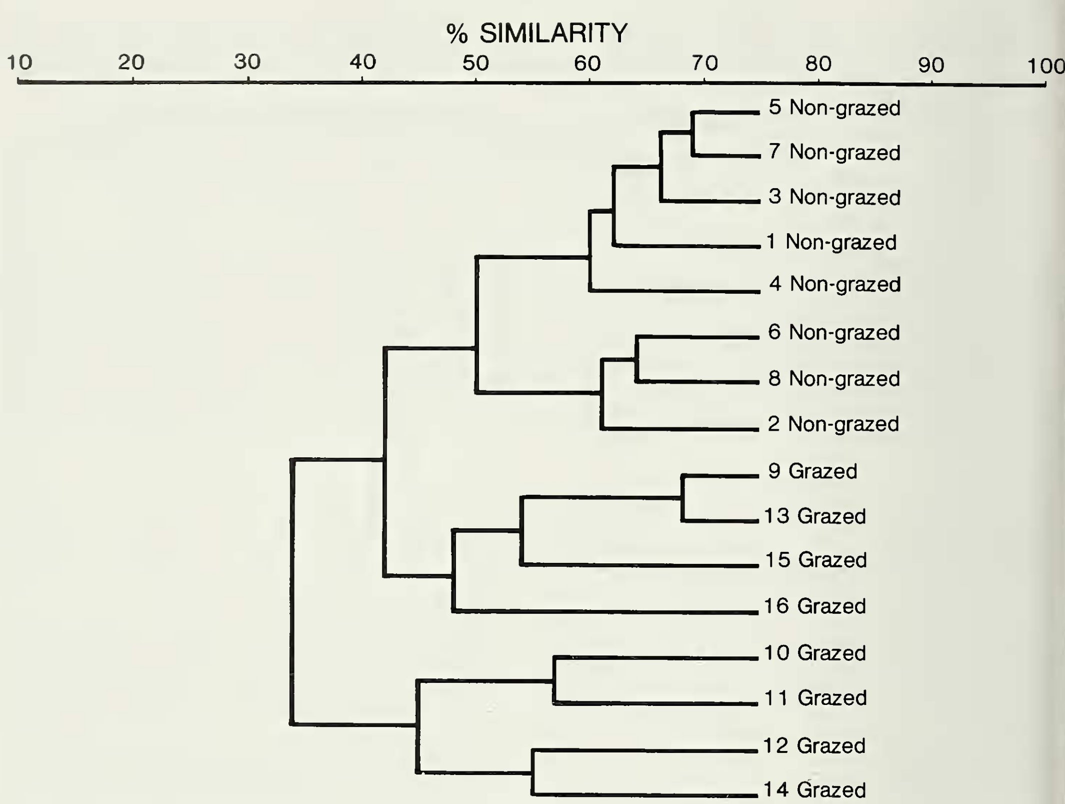

Fig. 2. Cluster dendrogram of grazed and nongrazed winterfät stands in Kane County, Utah. Cluster is based on similarity of plant species cover in site vegetation.

for laboratory analysis. Ludwig (1969) found that the surface decimeter of soil yields 80% of the information useful in correlating plant response with concentrations of essential mineral nutrients in the soil. Holmgren and Brewster (1972) showed that greater than 50% of the fine roots of plants (which included winterfat) in Utah desert communities are found in the top 15 cm of soil profile.

Soil samples were analyzed for texture (Bouyoucos 1951), pH, soluble salts, mineral composition and organic matter. Soil pH was determined with a glass electrode pH meter. Soluble salts were determined with a Beckman electrical conductivity bridge. Exchangeable calcium, magnesium, potassium, and sodium were extracted from soils with DTPA (diethylene triamine-penta-acetic acid; Lindsay and Norvell 1969). A Perkin Elmer Model 403 atomic absorption spectrophotometer was used to determine individual ion concentrations (Isaac and Kerber 1971). Phosphorus was extracted with sodium bicarbonate (Olsen et al. 1954). Organic matter was estimated from total carbon using methods described by Allison (1965).

Similarity indices comparing each stand to all other stands were calculated (Ruzicka 1958). These indicies were then employed to cluster winterfat stands following Sneath and Sokal (1973). Individual plant species were also clustered on the basis of niche overlap (Colwell and Futuyma 1971). Interspecific association patterns between plant species were computed using Cole's (1949) Index. Means and standard deviations were computed for all biotic and abiotic variables across the 16 stands. Prevalent species were selected on the basis of cover values (Warner and Harper 1972). Diversity indices were computed following Shannon and Weaver (1949) and McArthur (1972.) Statistical differences between grazed and ungrazed sites were calculated using Student's t-statistic.

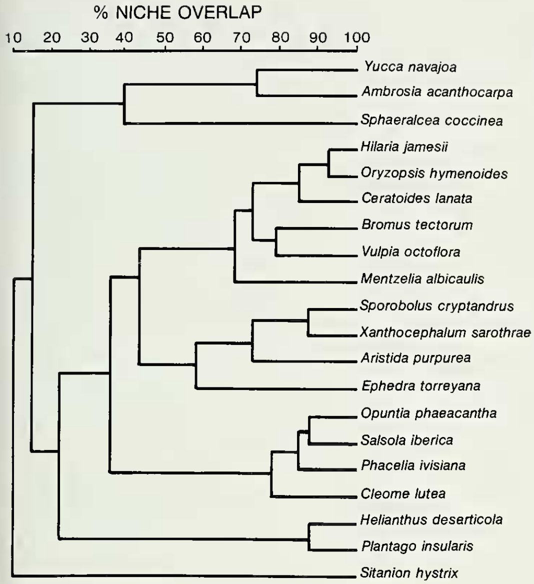

Fig. 3. Cluster dendrogram of plant species occurring in the study area. Cluster based on niche overlap relative to a species geographical distribution.

Results and Discussion

There were few differences in edaphic factors between grazed and ungrazed winterfat communities (Table 1). Significant differences between means were observed for percent silt, percent organic matter, and calcium concentrations. The higher levels of silt in the ungrazed area are probably due to the presence of the fence. The fence (net wire) would act as a barrier to blowing weeds and plant material and thus as a barrier to drifting soil. The more-abundant vegetation on the ungrazed sites would also create a barrier against which windblown silt would tend to accumulate. The differences in percent organic matter are also probably a function of increased vegetation cover. Mean differences in these three factors are relatively small, and floristic differences between grazed and ungrazed stands are, therefore, not considered to be caused by these soil characteristics.

Cluster analysis (based on vegetative similarity) clearly separated the grazed and ungrazed transects into two groups (Figs. 2 and 3). This separation reflects the effects of long periods of winter livestock grazing on vegetative composition. Grazing-induced change is also indicated by greater diversity within the grazed stands (Table 2). The greater plant diversities observed among grazed winterfat stands is expected. Cox (1976) noted that Charles Darwin observed greater diversity within grazed lands when compared with nongrazed lands (Cox et al. 1976). Harper (1977) also indicates that the great floristic diversity within the Chalk grasslands of Britain owes its existence to the selective grazing of livestock on potentially dominant plant species. Further research may better establish the occurrence of this phenomenon on other western ranges.

A major difference between grazed and ungrazed winterfat communities was in shrub cover (Table 2). Total live cover and litter cover were also greater on the ungrazed areas. Differences in community response to release from grazing pressure is best shown by differences in species cover (Table 3). The cover of winterfat on ungrazed areas was significantly greater than on grazed areas. Greater shrub cover on the ungrazed stands was entirely accounted for by the increased cover of winterfat. Although winterfat has been described as being relatively tolerant to grazing and as a "good natural increasor" (Blauer et al. 1976), it demonstrates little tolerance to winter use by cattle on our study sites, where it was potentially the dominant shrub.

Wide ecotypic variation is known to exist between winterfat populations (Stevens et al. 1977). Populations examined in this study were characterized by relatively large plants (up to three feet in height) with a growth form similar to big sagebrush (*Artemisia tridentata*). The genetic differences of this ecotype may account in part for its susceptibility to grazing.

Cover of cool-season grasses on the ungrazed sites was greater than on grazed sites, with the cover values of Indian ricegrass (*Oryzopsis hymenoides*) showing the greatest difference. This difference was probably due to grazing pressure during the late winter season when Indian ricegrass actively grows. Grazing while the grass is actively growing would stress the plant and reduce its capacity to compete. The warm-season grass species, galleta (*Hilaria jamesii*), which does not actively grow during the late winter grazing season, maintained nearly equivalent cover values be-

Table 2. Means and standard deviations (SD) of site factors and significance levels for the difference between the means for the grazed and nongrazed winterfat populations in Kane County, Utah. Significance levels were computed using the student's t-statistic.

Site Factor	Grazed		Ungrazed		Significance Level
	Mean	SD	Mean	SD	
Total life cover (%)	29.3	4.74	32.6	4.14	0.10
Exposed rock (%)	0.1	0.18	0.1	0.18	NS
Bare soil (%)	24.9	3.67	25.1	5.95	NS
Litter cover (%)	15.2	8.38	26.1	4.81	0.005
Cryptogram cover (%)	40.5	9.72	34.7	8.66	NS
Shrub cover (%)	7.2	3.18	13.4	4.25	0.10
Perennial grass cover (%)	20.4	7.21	18.8	8.21	NS
Annual grass cover (%)	4.2	3.26	5.1	3.79	NS
Perennial forb cover (%)	0.3	0.54	0.1	0.25	NS
Annual forb cover (%)	3.6	4.85	1.3	1.23	NS
Diversity:					
Shannon-Weaver	3.3	0.4	2.2	0.5	0.10
MacArthur	4.8	1.2	3.7	1.4	0.10

Table 3. Means and standard deviations (SD) of plant species cover occurring in grazed and nongrazed winterfat communities in Kane County, Utah.

Species	Grazed		Ungrazed	
	Mean	SD	Mean	SD
Ambrosia acanthocarpa	0.1	0.09	0	
Aristida purpurea	1.6	1.47	0.3	0.95
Bromus tectorum	0.4	0.48	0.7	1.11
Ceratoides lanata	2.3	1.44	13.9	4.83
Cleome lutea	0.1	0.09	0	
Ephedra torryana	1.0	2.24	0	
Helianthus deserticola	0.1	0.31	T	
Hilaria jamesii	15.9	8.07	16.1	6.47
Mentzelia albicaulis	1.0	1.20	1.1	1.19
Opuntia phaeacantha	0.2	0.49	0	
Oryzopsis hymenoides	6.7	2.88	10.5	4.21
Phacilia ivesiana	0.1	0.03	0.1	0.03
Plantago insularis	0.3	0.81	0.1	0.14
Salsola iberica	2.4	4.13	0.2	0.49
Sitanion hystrix	0		0.1	0.21
Sporobolus cryptandrus	3.3	1.97	0.1	0.17
Sphaeralcea coccinea	0.1	0.18	0.1	0.24
Vulpia octoflora	4.1	2.88	4.5	3.46
Xanthocephalum sarothrae	5.1	2.80	1.1	2.16
Yucca navajoa	T		0	

tween the two sites. Conversely, sand dropseed (*Sporobolus cryptandrus*), demonstrated increased representation on the grazed sites. This may be due to the pressure of livestock foraging, reducing competition on the grazed sites by opening up the vegetation cover and thus allowing room for expansion of sand dropseed. Sand dropseed is well adapted to sandy soils and will increase or even invade if the proper conditions are present. Other species showing increases on the grazed sites were snakeweed (*Gutierrezia sarothrae*) and Russian thistle (*Salsola iberica*). Both species are considered as increasers and/or invaders on rangelands in the western United States.

Percent cover of forbs was also greater among grazed stands. Russian thistle is primarily responsible for the increased represen-

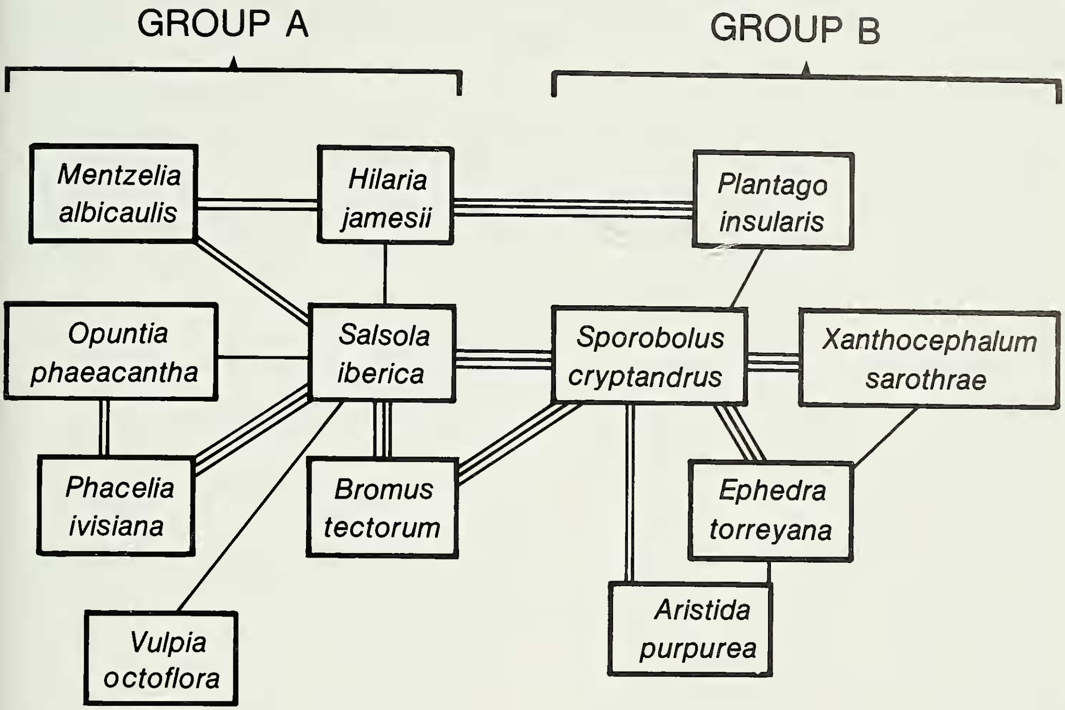

Fig. 4. Cluster of plant species associated with grazed and nongrazed sites as determined by Cole's (1949) Index. The more lines between the species, the greater the association. All associations are statistically significant.

tation of forbs on the grazed areas. Brotherson and Brotherson (1981) also reported greater cover of forbs in grazed sagebrush communities than in ungrazed communities. Increases in forb cover were due primarily to exotic annuals.

To further understand species interaction, niche overlap values were clustered to assess geographical association patterns among the species (Fig. 4). Five groups clustered together, three of which are of particular interest. These three groups centered around species that can be labeled decreasers, increasers, and opportunists. The remaining two groups seem of little significance. The decreasers group was characterized by winterfat and Indian ricegrass. This group also included species (winter annuals) that are not generally considered decreasers. However, all species in the group showed less cover on grazed than on ungrazed areas. The increasers include snakeweed, sand dropseed, purple threeawn (*Aristida purpurea*) and Torrey mormontea (*Ephedra torreyana*). Each of the species in this group had greater cover on the grazed sites and displayed some degree of dominance. The opportunists are generally considered unpalatable and showed increased cover on the grazed sites. This group is characterized by Russian thistle and prickly pear (*Opuntia phaeacantha*).

To define these relationships more precisely, we employed the use of Cole's (1949) Index of interspecific association (Table 4). In this case, two groups of species were apparent from the analysis. Group A contains seven species, five of which are annuals, whereas group B contains species that are mostly perennial. The species of group B are generally more important in the grazed sites with respect to cover values, and the species in group A show little preference for either side of the fence. Each group contains species that show positive affinities for species within that group and negative relationships for species found in the opposite group. The two groups

TABLE 4. Results of Cole's Index analyses with respect to the interspecific association patterns of species found growing in conjunction with winterfat populations in Kane County, Utah. Significance levels of the chi-square values are as follows: 0.05 = p≥ 3.85, 0.01 = p ≥ 6.64, and 0.01 = p ≥ 11.21.

	Positive associations				Negative associations			
Species	Species	X^2	Coef.	SD	Species	X^2	Coef.	SD
			Group "A"					
Bromus tectorum	*Salsalo iberica*	19.5	0.286	0.064	*Ceratoides lanata*	6.0	0.299	0.122
	Sporobolus cryptandrus	11.8	0.263	0.076				
Hileria jamesii	*Mentzelia albicaulis*	10.1	0.124	0.039	*Oryzopsis hymenoides*	9.5	0.578	0.187
	Plantago insularis	13.3	0.076	0.021	*Vulpia octoflora*	6.1	0.411	0.167
	Salsola iberica	4.2	0.054	0.026				
Mentzelia albicaulus	*Salsola iberica*	6.7	0.130	0.050	*Aristida purpurea*	5.6	0.702	0.296
Opuntia phaecantha	*Phacelia iviciana*	43.2	1.000	0.152				
	Salsola iberica	4.5	1.000	0.470				
Phacelia iviciana	*Salsola iberica*	8.9	0.694	0.233	*Ceratoides lanata*	5.2	1.000	0.441
Salsola iberica	*Sporobolus cryptandrus*	11.4	0.302	0.089	*Ceratoides lanata*	14.9	0.551	0.143
	Vulpia octoflora	4.6	0.551	0.157	*Oryzopsis hymenoides*	4.4	0.185	0.088
Vulpia octoflora					*Ceratoides lanata*	5.2	0.309	0.136
					Hileria jamesii	6.1	0.412	0.167
			Group "B"					
Aristida purpurea	*Ephedra torreyana*	6.1	0.080	0.032	*Ceratoides lanata*	8.6	0.551	0.187
	Sporobolus cryptandrus	8.5	0.343	0.118	*Mentzelia albicaulis*	5.6	0.702	0.296
Ephrdra torreyana	*Sporobolus cryptandrus*	13.1	1.000	0.277	*Oryzopsis hymenoides*	13.4	1.000	0.272
	Xanthocephalum sarothrae	4.9	1.000	0.451				
Plantago insularis	*Hileria jamesii*	13.3	0.076	0.021				
	Sporobolus cryptandrus	4.1	0.224	0.112				
Sporobolus cryptandrus	*Xanthocephalum sarothrae*	28.0	0.651	0.123	*Ceratoides lanata*	19.4	0.530	0.120
Xanthocephalum sarothrae					*Ceratoides lanata*	6.8	0.201	0.077

are bridged by two species: sand dropseed and, to a lesser extent, desert plantain (*Plantago insularis*). The existence of the two groups indicates the species belonging to each group are doing quite different things with respect to their present environment. The underlying reasons for the groupings are unknown.

Also of interest from the analysis is the fact that neither winterfat nor Indian ricegrass showed any positive correlations. In both cases, all indicated relationships with other species were negative. Winterfat, for example, had a total of 16 negative correlations out of a possible total of 20. Of these, 9 were significant ($p < 0.05$). With release from grazing, the individual plants of winterfat grow to be much larger in stature and increase in density (8,409 individuals/ha in the nongrazed area vs. 2,414 individuals/ha in the grazed areas). Such changes place winterfat plants in a highly competitive position with respect to other understory species. These changes would increase winterfat's crowding and shading ability. Most of the species showing negative association patterns with winterfat are shade intolerant.

Smith (1959) indicates that patterns of interspecific association between species can change with varying degrees of grazing pressure. Further, Cook and Hurst (1962), in a study done in the Escalante deserts of southern Utah, showed that negative association patterns intensified between winterfat and the two species Indian ricegrass and yellowbrush (*Chrysothamnus stenophyllus*). The intensified negative relationships that developed with yellowbrush happened because it and winterfat responded differently to varying grazing pressures. Winterfat was shown to decrease in the face of heavy grazing pressure whereas yellowbrush increased under similar grazing conditions. The intensification of the negative associations between winterfat and Indian ricegrass developed for opposite reasons. In this case both species showed increased prominence to release from heavy grazing, but under heavy grazing conditions their association patterns were essentially neutral. This suggests the development of strong competition between the two species when they are released from grazing and

growing sympatrically. Both cases appear to be happening with respect to winterfat and its interspecific association patterns as measured in our study. In the grazed areas of our study, winterfat is being eliminated as a result of winter use, and other species are expanding into the vacated space, thus creating the opportunity for increased competition and negative associations. Conversely, in the ungrazed sites winterfat is expanding in prominence, thereby creating conditions for the intensification of competition between itself and other species. Reasons are not always apparent or easily understood. To gain a total explanation, further studies of the autecology of the species involved seems necessary.

It is evident that release from winter grazing on the East Clark Bench allotment has had major impacts on the winterfat communities examined. Following 26 years without grazing pressure, floristic diversity decreased within the winterfat communities. Winterfat and Indian ricegrass showed dramatic increases in cover when released from grazing pressure. These species are likely the primary decreasers under the present management system, demonstrating lowered tolerance to grazing. It is reasonable to assume that damage to these species is due to late winter season utilization. Holmgren and Hutchings (1972) also report marked decreases in winterfat cover when the species was grazed during late winter after its growth had begun.

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